# Appendix L

## Dry Deposition Estimates Assuming No Decrease in On-Lake Concentrations Relative to Concentrations Observed at Urban Monitoring Sites

The conservative estimates of dry deposition presented here differ in only one way from the estimates presented in **Chapter 4**. Unlike the estimates in **Chapter 4**, they assume no decrease in the concentrations of PM and phosphorus over the Lake in the northwest and southwest zones compared to the concentrations measured at the urban monitoring sites of South Lake Tahoe (Sandy Way) and Lake Forest.

The details of the calculations and assumptions are provided in **Chapter 4** but a brief summary of the method of calculation is repeated here. The Lake was modeled as having four quadrants. Seasonal average concentrations of nitrogen species, phosphorus and PM mass were constructed from the TWS observations at representative sites in three quadrants and were estimated for a fourth quadrant based upon ratios of concentrations observed with shorter duration samples and at monitoring sites with the TWS. Diurnal variation in particle concentrations as averaged on a seasonal basis were inferred from observations of three particle size fractions obtained from BAMs collocated with the TWS. The seasonal diurnal concentrations were multiplied by a seasonally averaged diurnal deposition velocity based on data from a nearby meteorological site. For treatment of deposition velocity during offshore flow there was a differentiation between the near-shore and mid-Lake areas. Higher deposition velocities were applied in the near-shore areas during offshore flow.

Although the estimates of dry deposition provided here make the conservative assumption that concentrations measured on land were also representative of near shore and open water areas of the Lake, they are a useful standard for comparison with other estimates.

**Tables L-1, L-2, and L-3** present the lower, central, and upper estimates of dry deposition. They use the same assumptions and correspond directly to **Tables 4-10, 4-11, and 4-12**, except that they assume no decrease in concentrations on the Lake. The estimates for nitrogen species are identical to those in **Tables 4-10, 4-11, and 4-12**, because both (**Chapter 4** and **Appendix L**) assume nitrogen concentrations on the Lake are approximated by the observed concentrations at the urban monitoring sites.

**Table L-1. Lower bound estimates of seasonal and annual dry deposition to Lake Tahoe (metric tons/year) assuming mid-Lake concentrations are equal to observed concentrations on land.** Gaseous nitrogen (GN), aerosol nitrogen (AN), total nitrogen (TN = GN +AN), aerosol phosphorus (AP), and Mass from all sizes of PM. Assumes CAP on $1/R_a$ is 3 cm/s, particle deposition velocities are based on assumed diameters of 1, 5 and 15 microns for PM2.5, PM_coarse, and PM_large. Assumes a phosphorus concentration of 40 ng/m$^3$ (mostly in the fine fraction, with 32 ng/m$^3$ in PM2.5, 8 ng/m$^3$ in PM_coarse, and none in PM_large).

| 1_5_15 | Season | HNO3 | NH3 | GN | NH4 | NO3 | AN | TN | AP | PM2.5 | PMcrs | PMlrg | Mass |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| USCG-LF | Spring | 0.4 | 2.5 | 2.9 | 0.2 | 0.3 | 0.5 | 3.4 | 0.06 | 3 | 13 | 31 | 47 |
|  | Summer | 0.7 | 4.2 | 4.9 | 0.0 | 0.4 | 0.4 | 5.3 | 0.05 | 5 | 9 | 39 | 53 |
|  | Fall | 1.1 | 5.5 | 6.7 | 0.2 | 0.2 | 0.4 | 7.1 | 0.05 | 5 | 13 | 29 | 46 |
|  | Winter | 0.4 | 4.4 | 4.8 | 0.1 | 0.0 | 0.2 | 5.0 | 0.05 | 4 | 14 | 12 | 30 |
|  | Annual | 2.6 | 17 | 19 | 0.6 | 0.9 | 1.5 | 21 | 0.20 | 17 | 49 | 110 | 180 |
| TC-SW | Spring | 1.3 | 5.3 | 6.6 | 0.3 | 0.3 | 0.6 | 7.2 | 0.06 | 6 | 12 | 21 | 39 |
|  | Summer | 1.7 | 6.3 | 7.9 | 0.4 | 0.6 | 1.0 | 8.9 | 0.05 | 6 | 8 | 36 | 50 |
|  | Fall | 2.6 | 9.0 | 12 | 0.3 | 0.4 | 0.6 | 12 | 0.06 | 10 | 12 | 21 | 43 |
|  | Winter | 2.6 | 6.1 | 8.7 | 0.2 | 0.2 | 0.4 | 9.1 | 0.06 | 11 | 18 | 51 | 79 |
|  | Annual | 8.1 | 27 | 35 | 1.1 | 1.5 | 2.6 | 37 | 0.22 | 32 | 50 | 130 | 210 |
| CR-TB | Spring | 0.3 | 0.6 | 0.8 | 1.0 | 0.5 | 1.4 | 2.3 | 0.05 | 2 | 3 | 3 | 7 |
|  | Summer | 0.5 | 1.1 | 1.7 | 0.9 | 0.5 | 1.5 | 3.2 | 0.04 | 2 | 3 | 3 | 9 |
|  | Fall | 0.5 | 1.4 | 1.9 | 0.7 | 0.4 | 1.1 | 3.0 | 0.04 | 2 | 3 | 2 | 7 |
|  | Winter | 0.4 | 0.5 | 1.0 | 0.3 | 0.2 | 0.5 | 1.4 | 0.05 | 2 | 1 | 2 | 6 |
|  | Annual | 1.8 | 3.6 | 5.4 | 2.8 | 1.6 | 4.5 | 9.9 | 0.18 | 9 | 10 | 10 | 29 |
| SS-BL | Spring | 0.3 | 0.3 | 0.5 | 0.3 | 0.1 | 0.5 | 1.0 | 0.03 | 1 | 2 | 1 | 5 |
|  | Summer | 0.4 | 0.9 | 1.3 | 0.5 | 0.3 | 0.7 | 2.0 | 0.03 | 2 | 3 | 3 | 7 |
|  | Fall | 0.5 | 1.4 | 1.9 | 0.3 | 0.2 | 0.5 | 2.4 | 0.04 | 2 | 2 | 2 | 7 |
|  | Winter | 0.3 | 0.4 | 0.7 | 0.1 | 0.1 | 0.2 | 1.0 | 0.04 | 1 | 1 | 2 | 5 |
|  | Annual | 1.5 | 3.0 | 4.5 | 1.2 | 0.7 | 1.9 | 6.4 | 0.14 | 6 | 8 | 9 | 23 |
| All Lake | Spring | 2.2 | 8.7 | 11 | 1.8 | 1.2 | 2.9 | 14 | 0.20 | 12 | 30 | 56 | 98 |
|  | Summer | 3.3 | 13 | 16 | 1.8 | 1.7 | 3.6 | 19 | 0.16 | 15 | 24 | 81 | 120 |
|  | Fall | 4.8 | 17 | 22 | 1.5 | 1.2 | 2.7 | 25 | 0.19 | 19 | 30 | 54 | 100 |
|  | Winter | 3.7 | 12 | 15 | 0.7 | 0.6 | 1.3 | 16 | 0.19 | 18 | 34 | 67 | 120 |
|  | Annual | 14 | 50 | 64 | 6 | 5 | 10 | 74 | 0.74 | 64 | 120 | 260 | 440 |

Table L-2.  Central estimates of seasonal and annual dry deposition to Lake Tahoe (metric tons/year) assuming mid-Lake concentrations are equal to observed concentrations on land.  Gaseous nitrogen (GN), aerosol nitrogen (AN), total nitrogen (TN = GN + AN), aerosol phosphorus (AP), and Mass of all sizes of PM.  Assumes CAP on $1/R_a$ is 6 cm/s, particle deposition velocities are based on assumed diameters of 2, 8 and 20 microns for PM2.5, PM_coarse, and PM_large.  Assumes a phosphorus concentration of 40 ng/m$^3$ distributed between PM2.5, PM_coarse, and PM_large with 8, 24, and 8 ng of P/m$^3$ respectively.

| 2_8_20 | Season | HNO3 | NH3 | GN | NH4 | NO3 | AN | TN | AP | PM2.5 | PMcrs | PMlrg | Mass |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| USCG-LF | Spring | 0.6 | 3.7 | 4.2 | 0.3 | 0.4 | 0.7 | 5.0 | 0.16 | 3 | 21 | 54 | 78 |
| | Summer | 1.0 | 6.4 | 7.4 | 0.1 | 0.6 | 0.7 | 8.1 | 0.16 | 5 | 17 | 69 | 90 |
| | Fall | 1.7 | 8.3 | 10 | 0.3 | 0.4 | 0.7 | 11 | 0.16 | 5 | 21 | 50 | 76 |
| | Winter | 0.6 | 6.8 | 7.3 | 0.2 | 0.1 | 0.3 | 7.6 | 0.16 | 5 | 24 | 21 | 49 |
| | Annual | 3.9 | 25 | 29 | 1.0 | 1.5 | 2.5 | 31 | 0.63 | 18 | 83 | 190 | 290 |
| TC-SW | Spring | 1.9 | 7.8 | 9.7 | 0.5 | 0.5 | 1.0 | 11 | 0.16 | 6 | 19 | 37 | 62 |
| | Summer | 2.5 | 9.5 | 12 | 0.6 | 1.0 | 1.6 | 14 | 0.16 | 6 | 14 | 64 | 84 |
| | Fall | 4.0 | 14 | 18 | 0.5 | 0.6 | 1.1 | 19 | 0.16 | 11 | 19 | 36 | 66 |
| | Winter | 4.0 | 9.4 | 13 | 0.3 | 0.4 | 0.6 | 14 | 0.16 | 11 | 28 | 89 | 130 |
| | Annual | 12 | 40 | 53 | 1.8 | 2.5 | 4.3 | 57 | 0.65 | 34 | 80 | 230 | 340 |
| CR-TB | Spring | 0.4 | 0.8 | 1.3 | 1.6 | 0.8 | 2.4 | 3.7 | 0.16 | 2 | 5 | 5 | 12 |
| | Summer | 0.9 | 1.9 | 2.7 | 1.7 | 0.9 | 2.6 | 5.3 | 0.15 | 3 | 7 | 5 | 15 |
| | Fall | 0.9 | 2.2 | 3.1 | 1.1 | 0.8 | 1.9 | 5.0 | 0.15 | 3 | 5 | 4 | 12 |
| | Winter | 0.7 | 0.8 | 1.5 | 0 | 0.4 | 0.8 | 2.3 | 0.16 | 2 | 2 | 4 | 9 |
| | Annual | 2.8 | 5.8 | 8.6 | 4.9 | 2.8 | 7.7 | 16 | 0.62 | 9 | 19 | 18 | 47 |
| SS-BL | Spring | 0.4 | 0.5 | 0.9 | 0.6 | 0.2 | 0.8 | 1.7 | 0.15 | 1 | 4 | 3 | 8 |
| | Summer | 0.7 | 1.6 | 2.3 | 0.8 | 0.5 | 1.3 | 3.6 | 0.15 | 2 | 6 | 5 | 14 |
| | Fall | 0.9 | 2.3 | 3.1 | 0.6 | 0.4 | 0.9 | 4.1 | 0.15 | 2 | 5 | 4 | 11 |
| | Winter | 0.5 | 0.7 | 1.2 | 0.2 | 0.2 | 0.4 | 1.6 | 0.15 | 1 | 2 | 4 | 7 |
| | Annual | 2.5 | 5.0 | 7.5 | 2.2 | 1.2 | 3.4 | 11 | 0.59 | 7 | 18 | 16 | 40 |
| All Lake | Spring | 3.3 | 13 | 16 | 3.0 | 2.0 | 5.0 | 21 | 0.64 | 12 | 49 | 98 | 160 |
| | Summer | 5.0 | 19 | 24 | 3.2 | 3.0 | 6.2 | 31 | 0.61 | 16 | 44 | 140 | 200 |
| | Fall | 7.4 | 26 | 34 | 2.5 | 2.1 | 4.6 | 38 | 0.62 | 20 | 50 | 94 | 160 |
| | Winter | 5.8 | 18 | 23 | 1.1 | 1.0 | 2.1 | 26 | 0.63 | 20 | 56 | 120 | 190 |
| | Annual | 22 | 76 | 98 | 10 | 8 | 18 | 120 | 2.5 | 68 | 200 | 450 | 720 |

**Table L-3.  Upper bound estimates of seasonal and annual dry deposition to Lake Tahoe (metric tons/year) assuming mid-Lake concentrations are equal to observed concentrations on land.**  Gaseous nitrogen (GN), aerosol nitrogen (AN), total nitrogen (TN = GN + AN), aerosol phosphorus (AP), and Mass of all sizes of PM.  Assumes CAP on $1/R_a$ is 10 cm/s, particle deposition velocities are based on assumed diameters of 2.5, 10 and 25 microns for PM2.5, PM_coarse, and PM_large.  Assumes a phosphorus concentration of 40 ng/m$^3$ with the same distribution of phosphorus between size fractions as for the central estimate.

| 2.5_10_25 | Season | HNO3 | NH3 | GN | NH4 | NO3 | AN | TN | AP | PM2.5 | PMcrs | PMlrg | Mass |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| USCG-LF | Spring | 0.8 | 5.1 | 6.0 | 0.5 | 0.6 | 1.1 | 7.1 | 0.24 | 4 | 29 | 84 | 120 |
| | Summer | 1.4 | 9.3 | 11 | 0.1 | 1.0 | 1.1 | 12 | 0.23 | 5 | 24 | 110 | 140 |
| | Fall | 2.5 | 12 | 14 | 0.5 | 0.5 | 1.0 | 15 | 0.24 | 5 | 30 | 78 | 110 |
| | Winter | 0.8 | 9.9 | 11 | 0.4 | 0.1 | 0.5 | 11 | 0.23 | 5 | 34 | 33 | 72 |
| | Annual | 5.6 | 36 | 42 | 1.5 | 2.2 | 3.7 | 45 | 0.94 | 18 | 120 | 300 | 440 |
| TC-SW | Spring | 2.6 | 11 | 14 | 0.7 | 0.7 | 1.5 | 15 | 0.24 | 6 | 26 | 57 | 90 |
| | Summer | 3.5 | 14 | 17 | 0.9 | 1.5 | 2.5 | 20 | 0.23 | 7 | 20 | 99 | 130 |
| | Fall | 5.8 | 20 | 25 | 0.7 | 0.9 | 1.6 | 27 | 0.24 | 11 | 26 | 57 | 94 |
| | Winter | 5.9 | 14 | 20 | 0.4 | 0.5 | 1.0 | 21 | 0.24 | 12 | 39 | 140 | 190 |
| | Annual | 18 | 58 | 76 | 2.7 | 3.7 | 6.5 | 82 | 0.95 | 35 | 110 | 350 | 500 |
| CR-TB | Spring | 0.6 | 1.2 | 1.8 | 2.5 | 1.2 | 3.7 | 5.5 | 0.24 | 2 | 7 | 8 | 17 |
| | Summer | 1.3 | 2.8 | 4.1 | 2.6 | 1.4 | 4.0 | 8.1 | 0.23 | 3 | 10 | 8 | 21 |
| | Fall | 1.3 | 3.3 | 4.6 | 1.7 | 1.1 | 2.9 | 7.5 | 0.23 | 3 | 8 | 6 | 17 |
| | Winter | 1.0 | 1.2 | 2.2 | 0.6 | 0.6 | 1.2 | 3.4 | 0.18 | 2 | 3 | 6 | 12 |
| | Annual | 4.2 | 8.6 | 13 | 7.4 | 4.3 | 12 | 25 | 0.87 | 10 | 28 | 28 | 67 |
| SS-BL | Spring | 0.7 | 0.7 | 1.4 | 0.9 | 0.4 | 1.3 | 2.6 | 0.23 | 1 | 6 | 4 | 12 |
| | Summer | 1.1 | 2.5 | 3.6 | 1.3 | 0.7 | 2.0 | 5.6 | 0.22 | 2 | 10 | 8 | 21 |
| | Fall | 1.3 | 3.5 | 4.8 | 0.9 | 0.6 | 1.4 | 6.2 | 0.23 | 2 | 8 | 6 | 16 |
| | Winter | 0.8 | 1.0 | 1.9 | 0.3 | 0.3 | 0.6 | 2.4 | 0.17 | 2 | 3 | 6 | 11 |
| | Annual | 3.9 | 7.7 | 12 | 3.3 | 1.9 | 5.3 | 17 | 0.85 | 7 | 27 | 25 | 59 |
| All Lake | Spring | 4.7 | 18 | 23 | 4.6 | 3.0 | 7.5 | 30 | 0.94 | 13 | 69 | 150 | 230 |
| | Summer | 7.3 | 28 | 35 | 4.9 | 4.6 | 9.5 | 45 | 0.92 | 17 | 65 | 220 | 300 |
| | Fall | 11 | 38 | 49 | 3.8 | 3.2 | 6.9 | 56 | 0.93 | 21 | 72 | 150 | 240 |
| | Winter | 8.5 | 26 | 34 | 1.7 | 1.5 | 3.2 | 38 | 0.82 | 20 | 79 | 180 | 280 |
| | Annual | 31 | 110 | 140 | 15 | 12 | 27 | 170 | 3.6 | 71 | 280 | 710 | 1100 |

Clearly, in terms of mass, the deposition of large particles dominates the estimated total dry deposition of PM.

To illustrate the differences in the dry deposition estimates arising from alternate assumptions about concentrations on the Lake a comparison can be made between **Tables L-1, L-2, and L-3** (assuming no decrease on the Lake) and **Tables 4-10, 4-11, and 4-12**.

The central estimates of the dry deposition of PM (assuming no on-lake depletion, as in **Table L-2**) are illustrated in **Figure L-2**.

**Figure L-1** shows the seasonal estimates for dry deposition of total nitrogen by lake quadrant and chemical species, based on the central estimate displayed in **Table L-2**. **Figure L-1** is identical to **Figure 4-28** because neither assumes any depletion of nitrogen concentrations on the Lake.  It is clear that the estimate of total nitrogen deposition is dominated contributions from the south and north shores, primarily in the form of ammonia gas and secondarily in the form of nitric acid.

**Figure L-2** shows the dry deposition of PM mass by particle size based on the central estimate (**Table L-2**) with no depletion of on-Lake concentrations.  **Figure L-2** can be contrasted with **Figure 4-29**.  **Figure 4-29** differs because it assumes the modest decrease in concentrations on the Lake discussed in **Chapter 4** while **Figure L-2** does not.

**Figure L-1.   Contributions to total nitrogen deposition by quadrant, chemical species, and season.**   Corresponds to central estimate shown in **Table L-2**: maximum value of $1/R_a$ is 6 cm/s, characteristic particle diameters of PM2.5, PM_coarse, and PM_large are 2, 8 and 20 microns.



**Nitrogen Deposition (by Quadrant, Species, and Season)**
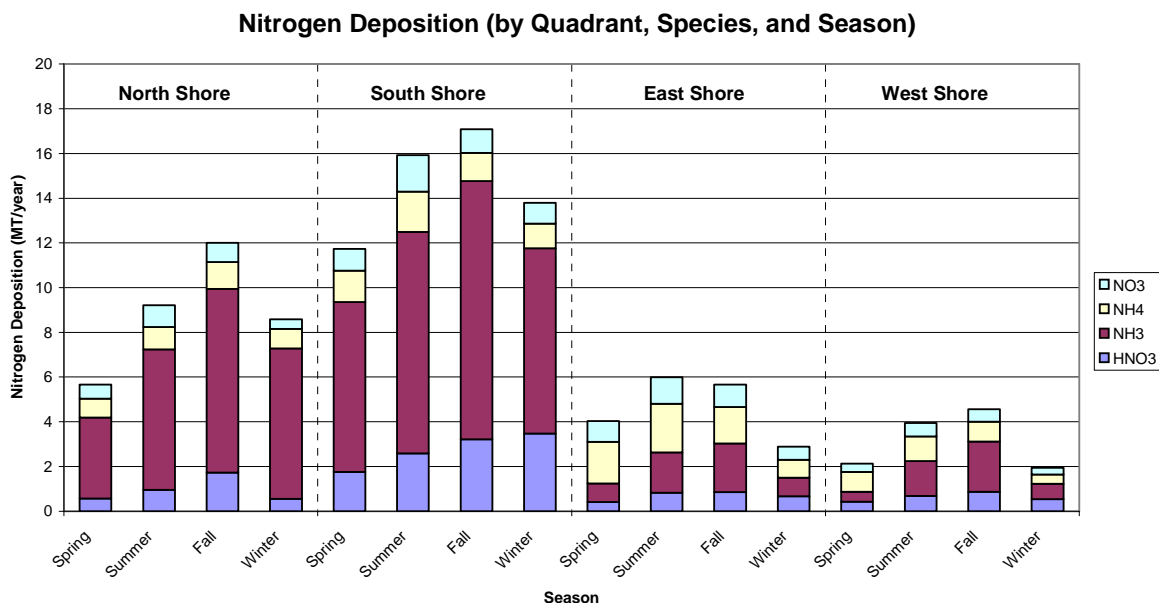
**Figure L-2.   Contributions to dry deposition of particle mass, by quadrant, season, and particle size.**  Uses central estimate assumptions regarding aerodynamic resistance and particle diameter corresponding to **Table L-2**.



**PM Deposition (by Quadrant, Size and Season)**